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USE OF ILLINOIS WATERS IN WABASH LOCOMOTIVE BOILERS[1]

By O. W. Carrick[2]

Most of the waters used for boiler purposes in Illinois (if not treated) will cause the formation of large amounts of carbonate and sulphate scale. We have read and heard much about the losses due to scale formation in boilers and of the many different compounds and methods by which this expensive evil may be overcome.

The treatment of water used by stationary boilers is a simple matter, but when one starts to soften the waters used by locomotives, he is confronted by a problem more complicated and of greater magnitude. Comparatively few railroads have given any system of water treatment a trial, due in part to the difficulty in presenting actual results and financial savings large enough to justify the required investment. Some of the methods of treatment tried did not produce encouraging results. For this reason treatment of boiler waters has been looked upon as uncertain in its beneficial results.

To obtain results in any business, it must first be systematized. In this paper I shall present some gratifying results obtained on the Wabash Railway by the systematic treatment of all Illinois waters used by this road, that contain sulphate of lime and magnesia, with just enough soda ash to neutralize this hardness and to provide an excess or sodium carbonate in water in the boiler.

In this state the Wabash runs over Decatur Division, which covers territory from St. Louis to Chicago and Danville, and Springfield Division, serving territory from Decatur to Hannibal, Quincy and Keokuk. In the spring of 1912 every water station on these two divisions of the Wabash was visited. The regular and all other available supplies were investigated and analyzed to determine the treatment necessary, and whether a better supply, needing less treatment, might be obtained. It was found that water for locomotive use was taken from 14 wells, 13 streams, 11 reservoirs and 1 "stream and well."

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[1] Read before the Illinois Section meeting, March 30, 1922.

[2] Water Engineer, Wabash Railway, Decatur, Illinois.

The following analyses, expressed in parts per 100,000, and other information cover present supplies on the Decatur Division:

PLACE	SOURCE OF SUPPLY	GALLONS USED DAILY	ALKALI SALTS	TOTAL HARDNESS	SULPHATE HARDNESS	SODIUM CARBONATE
Landers	Lake Michigan	300,000	2.2	13.8	1.3	0
Marley	6 inch well, 134 feet	60,000	6.0	47.2	8.2	0
Manhattan	10 inch well, 110 feet	80,000	1.0	44.0	4.0	0
Custer Park	Kankakee River	90,000	6.6	28.4	11.9	0
Campus	Ditch	30,000	2.3	27.5	12.5	0
Forrest	Dug well, 40 feet		4.5	44.5	14.0	0
Forrest	8 inch well, 100 feet	175,000	13.5	36.6	0	2.4
Gibson City	8 inch well, 57 feet	80,000	1.0	31.3	3.3	0
Mansfield	10–8 inch well, 213 feet	60,000	6.4	30.6	0	6.4
Bement	2–10 inch well, 144 feet	200,000	9.3	41.2	0	6.0
Danville	City-Vermillion River	60,000	1.1	25.9	6.4	0
Sidney	10 inch well, 50 feet	75,000	12.2	30.5	0	9.0
Sadorus	Ditch	25,000	3.8	31.2	7.2	0
Decatur	City-Sangamon River	550,000	2.6	27.8	5.4	0
Stonington	Well 34 foot City	35,000	2.4	30.6	0	2.4
Taylorville	Well 10 inch 80 feet	135,000	9.8	44.0	17.0	0
Morrisonville	Reservoir	30,000	5.6	16.4	8.4	0
Litchfield	City-Reservoir & Cr.	135,000	2.0	18.5	3.8	0
Mt. Olive	Reservoir-City	60,000	4.4	7.2	1.7	0
Edwardsville	Wells-City	60,000	2.8	19.4	2.4	0
Brooklyn	Miss. River-City	200,000	5.5	9.5	5.5	0

The Springfield Division waters show similar analyses, except that none contain free sodium carbonate.

It will be noted that the total hardness of the majority of these waters is high, but that the sulphate hardness in most cases is of such character that it requires only a moderate amount of soda ash to break this hardness. The alkali salts are not excessive. Our analytical work requires only total hardness and alkalinity determinations at wayside tanks by a traveling chemist and total dissolved solids determination in the laboratory, to obtain alkali salt content or foaming tendency of the waters.

Observation of boilers in the Wabash pumphouse at Mansfield has shown no scale formation on the heating surfaces after years of service. This water is obtained from a well 213 feet deep, which has a total hardness of 30.6 with natural sodium carbonate of 6.4 parts per 100,000. Waters of this character are desirable. In our work on water treatment we have been able to change the supply in several instances from the sulphate hardness water to water of the above character, doing away in this manner with the necessity for treatment.

With the above information, recommendations were made with estimate of cost and kind of plant for treating the water, with soda ash alone, similar to that at Mansfield, providing blow-off boxes in which engines were to be blown at terminals, and changing sources of supply where better ones were available. Two inexpensive methods, by which soda ash solution is forced into wayside tanks when raw water is flowing, were put in service. Where city water is used and the pumphouse is some distance from a wayside tank, a by-pass plant operated by back pressure is installed to by-pass raw water to a drum, where soda solution is displaced. A diaphragm is placed in the drum to separate solution from raw water. The back pressure is developed by putting an "orifice" in a thin plate in the discharge pipe and a flow of solution, in direct proportion to the flow of water, is discharged into the wayside tank. The other method is the forcing of solution into the tank by a small duplex pump. These plants call for an expenditure of from $150 to $800 depending upon type of plant and length of pipe line.

Failure to maintain continuous treatment results in scale on the flues and firebox sheets. This condition will exist if treatment is permitted to become 10 to 20 per cent too light. It is essential, therefore, to provide chemical supervision to keep instructions for the use of soda ash correct and to eliminate neglect of treatment. There must be also enough support from officers in charge to insure a minimum amount of neglect by the soda ash tenders.

One traveling chemist is able to take care of the treatment at 20 to 30 water stations. Such a man carries an analysis case with sampling bottles and chemicals, for collecting and analyzing raw and treated waters while at the plant. From the analysis of the raw water he calculates the number of pounds of soda ash needed to treat it. From the analysis of the treated water he determines amount of soda ash used. If the raw water has changed in hardness, directions are changed accordingly. If the treatment does not check the directions he takes steps to locate trouble. The analytical work requires from 10 to 20 minutes and it is his duty to see that the treatment is correct before he leaves for the next water station. He is required also to ride locomotives and to advise enginemen as to the effects of using treated water and the amount of blowing off of boilers necessary; to check up the use of soda ash in stationary boilers; to watch the washing of locomotives to see that no scale is given up, to collect samples of water from boilers on different occasions in order to get a check on treatment in general, to note if enginemen are blowing enough water out of boiler to keep the water from foaming and to check the blowing of engines at terminals.

With the addition of soda ash to water the foaming tendency of the water is increased. When a lime-soda-ash softener is used part of the incrusting solids will settle out, but the the alkali soda salts and the foaming tendency remains. With our method of treatment we do not have settling tanks, for we find that the lime salts cause no trouble in the boilers as these solids when precipitated are blown out through a properly located blow-off cock.

We have made road tests and thousands of waters taken from boilers have been analyzed, the results of which show that the water will foam in a locomotive boiler when the concentration of dissolved solids is about 2400 parts per million. It is necessary then to do enough blowing to keep the solids below this concentration. To relieve the enginemen of this work engines are blown by hostlers at terminals before being put in the roundhouse. This terminal blowing is essential as the locomotive is dispatched with water in good condition.

Much has been said about the heavy cost of blowing out necessary to keep down foaming. We realize that considering the waste of fuel and water, the cost of blowing off is possibly the major part of the cost of water treatment, but this cost for any given territory may be easily calculated. On our Decatur Division, where the treatment will average 0.7 pounds of soda ash per 1000 gallons of water, about 4.5 per cent of the water will have to be blown out to keep boiler from foaming. This will entail a fuel waste of approximately 1.2 per cent of the coal used. The total cost of the coal and water wasted would be about $0.03 per 1000 gallons. This cost of blowing out should never deter one from treating water, as it is much more than off-set by fuel saving and other benefits resulting from clean heating surfaces.

ENGINE FAILURES DUE TO LEAKY FLUES, STAY BOLTS, FIRE BOXES, ETC.

The metal in locomotive boilers is continually undergoing excessive strains when covered with a coat of scale, which results in weakening cracks, checks and other failures. A failure due to boiler leakage is an expensive one since it involves usually giving up the train and having another engine go out after the train and the failed engine. When this engine is brought into the terminal, inspection may show that, on account of the heavy scale formation, the flues and firebox are in such condition as to require new tubes or patching of the firebox before it may again be dispatched, resulting in an engine being out of service for several days, with more locomotives necessary. Wabash locomotive boilers, after being in service four years, contain practically no scale. The following table shows improvement in the way of reducing leakage failures for the year 1921, as compared with the year 1911, the latter being the year before treatment was started.

DIVISION	NUMBER OF FAILURES		DECREASE	MILES PER FAILURE	
	1911	1921		1911	1921
			per cent		
Decatur............	232	4	98.3	20,878	989,068
Springfield...........	57	0	100.0	33,303	No failures
Total.............	289	4	98.6	27,090	1,173,618

It will be noted that on the Decatur Division the failures were reduced 98.3 per cent and on the Springfield Division all failures were eliminated, making a decrease for both Divisions of 98.6 per cent. The mileage per failure increased from 27,090 in 1911 to 1,173,618 in 1921.

In July 1917, 25, 2-10-2 engines with 23 foot flues were placed in service on Decatur Division, before treatment considered our hardest water Division. During the 4½ years of service there have been seven failures due to leaky flues. The average time to the first resetting of flues was 39 months and the average flue mileage on the ten highest engines is 116,477. Engine 2525 (which is now in shop for its first set of flues) made 127,313 miles. Our passenger engines are making from 200,000 to 300,000 miles between flue resettings. It is not an unusual occurrence to obtain permission to run flues beyond the four-year limit set by the Goverment as the time in which all flues should be renewed.

FIRE BOX RENEWALS

I do not have figures showing the decrease in firebox renewals for locomotives running in Illinois alone, but this information, covering the road where treated water is used, shows a reduction for the last three years of 93 per cent over 1915, the year in which the effect of water treatment on this part of the locomotive work was really felt.

STAY BOLT RENEWALS

There has been a decided decrease in staybolt breakage in engines operating in Illinois since water treatment was started, and for the past few years about one bolt per engine per year is renewed. The 2-10-2 engines previously mentioned have 3047 staybolts, including 2320 rigid stays, 639 American flexible stays and 88 Tate flexible staybolts. There have only been fourteen staybolts broken on the entire 25 engines. On our Canadian Division, where treatment has not been established and which has not as bad water as Decatur before treatment was started, the broken bolts per engine per year are 52.

FUEL PERFORMANCE

Marston Taylor Bogert, in an address before the American Chemical Society, said: "In the United States the average thickness of locomotive boiler scale is $\frac{1}{16}$ inch; this means a loss of at least 13 per cent in fuel efficiency, or, for our 51,000 locomotives alone, a total annual loss may be estimated conservatively at 15 million tons of coal." Up to 1919, our record of fuel saving on the basis of pounds of coal per 100-ton miles shows a decrease of 21.25 per cent over 1912. We do not attribute all of this decrease to water treatment, as the extended use of the superheater engines and brick arch, and the formation of a competent fuel organization have had also their bearing on this saving.

In the preceding pages, I have tried to cover in a general way our method of treatment of waters used in Wabash locomotives in Illinois, together with a few of the results obtained. By systematic treatment of these waters we have been able to accomplish the following principal results:

1. Practical elimination of engine failures due to leaky flues, firebox, staybolts, mud rings, etc.
2. Reduction of fuel consumption by keeping heating surfaces comparatively free from scale.
3. Reduction of staybolt breakage and firebox renewals and repairs to a very low figure.

4. Decreased cost of boiler repairs from 30 to 65 per cent.

5. Increased mileage between boiler washings to any desired amount.

6. Operation with fewer engines, due to engines not being held in roundhouse and shops for boiler work.

I believe that the majority of men present are users of steam made by stationary boilers and are interested in keeping them free from incrustation. Our method of doing this is to pump soda ash solution directly into the boiler, twice daily, by means of a small duplex pump. The amount to be pumped is calculated from the amount of water evaporated and the sulphate hardness of the water. All heating surfaces are kept practically free from scale, which results in long life of boiler and in greater efficiency.

DISCUSSION

A. S. BEHRMAN.[3] Mr. Carrick has made several statements that have left me wondering. The average permanent hardness of the Illinois waters Mr. Carrick discusses is slight as compared with the bicarbonate hardness. Mr. Carrick stated that the average quantity of soda ash required per thousand gallons is about 0.6 pound, equivalent roughly to a permanent hardness of 1 grain per gallon. The temporary hardness in these waters, on the other hand will run anywhere from 6 to 20 grains per gallon. In other words, the soda ash treatment is a good deal like removing the tail of the dog, but leaving the dog there. This temporary hardness is going to appear, upon evaporation of the water, as a deposit of scale or sludge and the sediment formed will hasten foaming. It is an accepted fact that sediment in water tends to make the water foam. As a matter of fact, some authorities state that waters free from sediment will not foam even with extremely high concentrations of soluble salts. I have been wondering why the Wabash Railroad decided on this method of water treatment, which considers such a small part of the substances which form scale or sludge and cause foaming

O. W. CARRICK:[2] In the paper I gave an instance of practically no scale being formed in our Mansfield Illinois pumphouse boiler, which uses water with a total hardness of 30.6 and sodium carbonate of 6.4 parts per 100,000.

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[3] Chief Chemist, International Filter Company, Chicago, Ill.

After plants have been installed over a division and enough soda ash has been used to neutralize the sulphate hardness, making the treated water similar to the natural non-scaling waters, the total hardness and suspended matter is precipitated in the form of a soft sludge in the water leg of the locomotive firebox. Critical examination of the deposit has shown that the large portion settles along the back leg, which is the point of least circulation.

Our blow off cocks are located in the left back corner and have a perforated pipe connected to them which extends across the full width of the firebox and lies on the back mud ring. To prevent foaming it is necessary to do enough blowing to keep the alkali salts or dissolved solids below a concentration of 2400 parts per 1,000,000 by weight. Incidental to this blowing the sludge is also removed. Inspections of the interior of boilers, when due for washout, have shown that it is possible to run locomotives indefinitely without a washout and without any foaming, if the blow off cock is properly used.

C. R. KNOWLES:[4] It is difficult to fix a definite concentration of dissolved solids in a locomotive boiler without foaming. Whether a boiler will foam or not depends upon other factors, chief among which is the amount of matter in suspension.

Mr. C. H. Koyl, of the Chicago, Milwaukee & St. Paul, has stated that it is possible to carry 1,000 grains per gallon, while I have known cases where violent foaming occurred with a concentration of only 50 grains per gallon. Therefore, it is impossible to fix a definite concentration at which foaming will occur.

We began treating water on the Illinois Central about years ago. During this time I believe we have used every kind of treatment known from potato peelings to barium hydrate. We do not confine ourselves to any one form of treatment. For example, we have water treatment plants using lime and soda ash at twelve stations in Iowa and eight in Illinois. We are now also using interior treatment or what is commonly known as boiler compound at 75 stations over the system. We have several filter plants in operation for the removal of suspended matter. Only about 25 per cent of the water in Illinois requires treatment. Seventy-five per cent of the water either does not require treatment or may be treated with soda ash or some form of boiler compound. It would certainly be a mistake to recommend the soda ash treatment as a remedy for all boiler evils, for, as stated by Mr. Behrman, removing the sulphate hardness and leaving the carbonate hardness in the water is certainly not complete treatment. In fact, we have many waters high in carbonates and in some cases practically devoid of sulphates.

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[4] Superintendent, Water Service, Illinois Central Railroad, Chicago, Illinois.

A. S. BEHRMAN:[3] Foaming is in some cases as important, if not more important, than scale, for a scaly boiler may frequently be operated, even though inefficiently, where a foaming boiler cannot be operated at all. Foaming is not entirely dependent on the factor Mr. Carrick emphasizes, that is, on the concentration of soluble salts. It has been shown definitely that the concentration of soluble salts may be carried much further without foaming, if suspended matter is absent.

Furthermore, the soda ash treatment alone does not provide the hydrate alkalinity certainly protective to boilers and which minimizes corrosion. This hydrate alkalinity is secured, of course, when lime is used. All things considered, I do not see any comparison between this partial treatment with soda ash, and a combined lime-soda treatment properly carried out. Proper lime-soda treatment will provide a water that is non-corrosive, that will form absolutely no scale, and that will yield a minimum of suspended matter upon concentration. The soda ash treatment alone will not do these things.

O. W. CARRICK:[2] The question arises as to whether it would be more economical to treat water by the lime-soda ash process or by soda ash alone. Mr. Behman states that, with the former method, the alkali salts in a boiler may be carried to a higher concentration before foaming takes place, due to the lime solids being removed.

The saving due to the reduction in blowing off may be calculated at a definite amount per 1000 gallons of water evaporated and set against interest, depreciation, and operating charges for the softeners. At the same time, it must be remembered that there is a possibility of one or more or these plants not operating properly. This would mean an increase in lime solids which would result in lowering the concentration to a point possibly not much greater than with other methods of treatment.

By using soda ash alone in a systematic way, very gratifying results have been obtained on the Wabash. With due consideration to other methods for scale prevention, we feel that our method is quite satisfactory and least expensive.

C. R. KNOWLES:[4] The American Railway Engineering Association, Committee on Water Service, prepared definitions on foaming, together with recommendations for the prevention of foaming. I was a member of the Committee and know that the conclusions were arrived at only after extensive study had been made.

This Committee went on record as stating that foaming was primarily caused by suspended matter. I think one of the best examples of boiler water treatment is that on the Great Northern Railroad. If I am correctly informed, there is one district on the Great Northern where they are operating successfully with water containing from 60 to 80 grains of soda ash per gallon. It should, be understood, of course, that the locomotives on this district used only treated water, as the addition of a half a boiler of untreated water would create a condition of foaming that would be worse than the use of the water without treatment.

The results obtained on the Great Northern are very convincing. With regard to suspended matter being an important factor in the foaming of locomotive boilers, several roads have installed filters in connection with their water softening plants for the removal of all suspended matter after treatment. This should go far towards keeping down the quantity of suspended matter in the boiler. The installation of filters will pay undoubtedly a handsome return on the investment through reducing foaming in locomotives.

G. C. HABERMEYER:[5] Regarding the difference in practice of the different railroads, we might cite the case at Mendota where the C. B. & Q. and the I. C. have wells within 400 feet. I understand both supplies were treated, but after a number of years the C. B. & Q. R. R., although they have a plant available, are using the water without treatment, while the I. C. consider it proper to treat their water from the same source.

C. R. KNOWLES:[4] In regard to Mr. Habermeyer's reference to Mendota. It is true we have a plant at that point, where the water

[5] Civil and Sanitary Engineer, Urbana, Ill.

is treated with lime and soda ash. I may add, however, that we use very little soda ash, as the water runs 12 or 15 grains carbonate hardness, with only a trace of sulphates. This is a case where the soda ash treatment as recommended by Mr. Carrick would be of little benefit.

As stated by Mr. Habermeyer the C. B. &. Q., only a few hundred feet away from us, use this water without treatment. The Q. at one time maintained a plant at this point and afterwards abandoned it and treated with soda ash for a time. If I am correctly informed, the reason for abandoning the plant was that it did not provide for increased consumption. While the water we use at Mendota is not considered among our worst waters, at the same time we feel justified in treting it for the reason that we intend to equip this entire district with treatment plants.